VOL. XLII, NUMBER 5 WHOLE NUMBER 374

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS:

C. S. BEALS
Dominion Astronomer
Ottawa

J. A. PEARCE
Dominion Astrophysicist
Victoria, B.C.

A. THOMSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED BI-MONTHLY
(*Six numbers per year*)

September-October, 1948

PRINTED FOR THE SOCIETY
TORONTO: 3 WILLCOCKS ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XLII, No. 5 SEPTEMBER-OCTOBER, 1948 WHOLE No. 374

Articles PAGE

The Joint Meeting of the American Astronomical Society and the Astronomical Society of the Pacific, Pasadena, California, June 28 - July 1, 1948 ..... *K. O. Wright* 201

The "Amateur" Astronomer ..... *Frank R. Vaughn* 209

Wave-length Standards for Radial-velocity, Determinations, III. The A-Stars with Single Prism Dispersion. *R. M. Petrie* 213

Wave-length Standards for Radial-velocity Determinations, IV. The Solar-type Stars with low dispersion. ..... *Jean K. McDonald* 220

A New Projection Instrument for the Rapid Determination of Stellar Radial Velocities . . . (With Plates VI, VII) ..... *R. M. Petrie and S. S. Girling* 226

Why North at the Top? ..... *George Parson* 233

Rockets and Space Travel ..... *Willy Ley, J. W. Campbell* 235

Review of Publications

Astronomy, by W. L. Kennon (*C.A.C.*); Nicolaus Copernicus, by J. F. Dobson and S. Brodetsky (*C.A.C.*); Practical Astronomy, by G. L. Hosmer (*K.O.W.*) 238

Out of Old Books

The Titius-Bode Law and the Discovery of Ceres ..... *Helen Sawyer Hogg* 241

Notes and Queries

Copernicus's "De Revolutionibus," its Nature and Contents; Historical Notes in Scientific Text-books ..... *C. A. C.* 247

Statement regarding Fees of the R.A.S.C. 248

Announcing * **New Astronomy Charts** *

For the amateur's scrap book, the professional's fingertips, the classroom or the lecture hall.

Ptolemy's Solar System—Tycho Brahe's Theory—Theory of Copernicus—Our Solar System's Superhighways—Kepler's Two Laws Charted—How Big? How Far?—Planetary Configurations—Mathematics finds a Planet—Planets in 1948—Apex of Sun's Way—When the Sun Blacks Out—Favorable Mercury Elongations—Earth-Venus Positions—The Seasons—The Tides—Our Moon in 1948—Gravity, Wobble, True Moon Path—Earth and Mars in Opposition—Mars in Retrograde—Atmospheric Refraction—Related Meteor and Comet Orbits—Power in Space—Orbit of Halley's Comet—The Stellar Parallax—Other sets in preparation.

The set above, 25 charts 8½ x 11 punched for loose leaf folder . . . . . $2.75 postpaid — Single wall charts 27 x 35 inches . . . $2.75 each. Special Discounts on quantity orders.

ASTRONOMY CHARTED

4 MASON ST., WORCESTER, MASS., U.S.A.

PRINTED IN CANADA

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XLII, No. 5 SEPTEMBER-OCTOBER 1948 WHOLE No. 374

THE JOINT MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY AND THE ASTRONOMICAL SOCIETY OF THE PACIFIC, PASADENA, CALIFORNIA

June 28–July 1, 1948

By K. O. WRIGHT

MEETINGS of the American Astronomical Society have been held on the West Coast about once a decade (previous years were 1915, 1923, and 1939). As the observatories of California are well-known for the hospitality of their staffs as well as for their famous instruments, the joint meeting of the American Astronomical Society and the Astronomical Society of the Pacific in Pasadena, June 28-July 1, was awaited with great interest. It was the good fortune of the writer to have the opportunity of driving with his family from Victoria to attend these meetings, to present papers by members of the Observatory staff, and also to spend a few days at the Mount Wilson Observatory offices and at the Lick Observatory.

The southward journey began on June 22 and we were favoured with the best weather of the year throughout Washington, eastern Oregon, Nevada, and the Yosemite Valley—in southern California the weather is uniformly good throughout the year we are told! We arrived in Pasadena on Sunday afternoon after a pleasant drive through the nearby orange and lemon groves—in contrast to the heat and brownness of the hills passed through in the morning—in time

to register at the California Institute of Technology and to become acquainted with other astronomers and their families who were staying at the same hotel.

Registration continued on Monday morning, following which a trip was organized to visit the offices of the Mount Wilson Observatory and the optical shops of "Caltech" where the principal work on the 200-inch mirror was performed. However, Dr. Ernest A. Hodgson, Dominion Seismologist, was in Pasadena at the time and had arranged that we should visit the Seismological Laboratory to see Dr. H. Benioff and to discuss the performance of the new Benioff vertical Seismograph which had been installed at the Dominion Astrophysical Observatory earlier in the month. This time was well spent and the performance of the seismograph should be improved as a result.

In the afternoon the meetings had been scheduled to begin in one of the lecture rooms in "Arms" Building but it was soon filled to overflowing and the opening ceremonies were transferred to the large physics lecture room in "Bridge"—where they continued though even it was overcrowded at times. (I am told that the registration, including families, exceeded 370, to make the largest aggregation of astronomers in the history of the societies.) Following the address of welcome by President DuBridge of the California Institute of Technology, Dr. Struve, President of the A.A.S. undertook the task of directing the flow of astronomical discourse into a smooth and orderly stream. In view of the sixty-four papers on the program, the time for each was cut from ten to eight minutes and for some time the papers were presented well within the time limit and discussion was strictly limited. No doubt both authors and audience were somewhat over-awed by the large assemblage for, although discussion was not overwhelming at any time, the sessions later became more free and less formal in accordance with the usual custom at meetings of the A.A.S.

It is difficult to pick out individual papers for comment from such an array. In fact the great variety and relatively few papers on any one subject indicate how far astronomy has advanced since meetings such as this were first instituted. There were papers on comets and meteors in the best tradition of classical astronomy; others dealt with variable and double stars, with spectra, line intensities and the

atmospheres of metallic-line stars, and with external galaxies. The following papers seemed of special interest to the writer and will serve as examples:

"Stellar Spectra in the Region of the Obscuring Clouds of Ophiuchus and Scorpius" by Otto Struve and M. Rudkjobing reported on emission-line stars similar to the T Tauri variables discovered by Joy which seem to appear in regions of nebulosity. In this case all stars showing emission are main-sequence stars of types K-M, whereas B-type stars in the same region appear normal. It was suggested that these faint stars derive their energy as a result of bombardment by small particles from the nearby nebula.

"The Nuclear and Nebular Spectra of the Planetary Nebula NGC 2392" by O. C. Wilson was a study of high-dispersion coudé plates taken at Mount Wilson. They showed the familiar double structure for most lines but, surprisingly, those of Ne V at λλ 3346 and 3426 were single, indicating that these lines arise in some other part of the nebula, probably the nucleus. Wilson found that the radial velocities of the different lines are a function of excitation potential and postulated a rapidly expanding atmosphere with the velocities a function of depth.

"The Research Program of the Light of the Night Sky" by C. T. Elvey and F. E. Roach told of an expanded program sponsored by the U.S. Navy, to study the upper atmosphere by photometry and spectroscopy of the night sky. Observations are to be made with specially-designed cameras from California to Alaska and with aircraft up to heights of 20,000 feet. "Practical Use of Photocells at Maximum Performance" by Gerald E. Kron indicated that new amplification circuits, combined with photoelectric cells developed in the past few years, have opened almost unlimited fields for research with small telescopes. The efficiency of such cells has now been increased to nearly 90 per cent. of the theoretical value and Kron estimated that, with refrigeration, accurate observations of stellar magnitudes could be made on 12th magnitude stars with the 12-inch refractor of the Lick Observatory, and that 17th or 18th magnitude stars could be observed with the 100-inch telescope.

While sessions for papers continued until Wednesday afternoon, there were several excursions to vary the program. On Monday evening, Dr. Dinsmore Alter arranged for a special preview of the

July lecture on "A Trip to the Moon" at the Griffith Planetarium. A brief discussion of the possibilities of lunar travel prefaced the demonstration, following which the audience was taken to the equator, where the sky was seen to be quite different from that observed from Los Angeles. From that point the trip to the moon was begun and a special new instrument was brought into play to observe the moon at different distances, while backward glances showed the earth as a ball with polar caps, oceans, and continents, revolving in its daily motion. At the closest approach, the moon covered about one-third of the dome and details on its surface and possible causes of the formations were discussed.

On Tuesday afternoon the Societies journeyed to Mount Wilson and were instructed in the details of the solar telescopes and were shown the sun-spots and prominences which were visible on the sun, both directly and through the spectrohelioscope. Lemonade was served by members of the staff—a welcome treat on a warm afternoon. Later on, while the children enjoyed the tame deer and squirrels about the Mount Wilson Hotel, another session for papers was held. The crowd on the mountain was so great that dinner was served in two sittings and while one group was eating, the other was shown the excellent colour film prepared by Edison R. Hoge on the 200-inch mirror and its transportation to Palomar. In the evening the telescopes were available for observation and nearly everyone saw either Saturn or Jupiter through the 100-inch and the double star, α Herculis through the 60-inch. Saturn was rather far west but even with the relatively poor seeing produced by the low altitude the details of the rings were seen clearly.

Thursday had been set apart for the trip to Palomar Mountain which, by the coast road, is more than 140 miles from Pasadena. We drove down with Dr. and Mrs. Hodgson and thoroughly enjoyed the trip through the orange groves, past the oil wells and along the coast highway before turning inland for the last fifty miles, first through relatively brown land and finally up the mountain over gradual but steady grades till the plateau at the top, at an altitude of 5,500 feet, was reached. Lunch was enjoyed in the ample picnic grounds before we went through the astronomical museum—at present displaying only transparencies of astronomical objects—and then to the big dome which contains the 200-inch Hale Telescope. Usually visitors are re-

stricted to a view of the telescope but on this occasion they were admitted both to the floor of the dome and to the gallery above, which revolved with the dome, and from which a good view of the 200-inch mirror itself could be seen. The telescope gleamed in its gray coat, and when moved it swung almost noiselessly and very quickly to the desired position.

The program of the afternoon was the "scientific" dedication of the Hale telescope—the formal dedication had been held on June 3. Everyone gathered on the floor of the dome and was welcomed by Dr. Ira S. Bowen, director of Mount Wilson and Palomar Observatories. The optics of the telescope were described by Dr. John A. Anderson, who included the story of the 200-inch, 14½-ton piece of glass which was finally placed in the telescope late in 1947, twelve years after being cast in Corning, N.Y. The final figuring has been done at Palomar and it is now considered "very good." Bruce H. Rule, head of the engineering staff in charge of the project, gave a detailed description of the mechanics of the telescope and noted how accurately the 500-ton mounting kept the mirror pointing at the star in any position because the very accurate control system allows for variations in refraction, etc. The main weight of the mounting is supported by the giant horseshoe which rolls on a thin pressurized film of oil. In order to be completely independent of power failures, the eighteen buildings on the mountain have been set up as a self-contained unit, and to co-ordinate the system there are about four hundred miles of wire in the Observatory and about one hundred miles relating to the telescope itself. The whole development is surely a marvel of engineering achievement, though even yet the ultimate has not been attained and tests are to continue for some time to come.

The program drawn up for the Hale Telescope was outlined by Dr. Walter Baade. While the cosmological problem involving the red-shift of extra-galactic nebulae is one of the foremost problems of our day, it will be some time before it will be possible to evaluate results obtained with the 200-inch telescope. It will be necessary to obtain new magnitude scales down to $22.^{m}5$, much of which may be done with the photocell. Using this scale, the Cepheid variable stars will be studied, first in our own system and then in external galaxies in order to improve our estimates of the distances of these objects—though absorption in space and internal absorption within the galaxies

themselves will pose difficult problems. With these new data the redshift of these galaxies will be examined anew and fainter galaxies will be studied in an attempt to solve the principal problem, "Is our universe really expanding?"

Another problem in which Dr. Baade is particularly interested is the study of the properties of stars in galactic systems. He has found that there seem to be two principal classes of stars in our universe: population I consists of stars with which we are acquainted in the neighbourhood of the sun whose masses, luminosities, and spectral types follow the well-known Russell diagram of main-sequence and giant stars; population II consists of stars, usually in early-type nebulae and globular clusters, and is characterized by giant, overluminous stars of types *F* to *K*, and numerous stars in the "Hertzsprung gap" between the giant and main-sequence branches of the Russell diagram. Baade would like to extend his studies farther into the Andromeda nebula than has been possible yet. He considers that on nine per cent. of the nights, long exposures with the Hale Telescope will give results which will be valuable for such a study.

While the spectrographic work of the 200-inch telescope is considered one of the most important and promising fields of investigation, the equipment for use at the coudé focus is only now being prepared. It may be a year or more before work is begun on the principal problem—the determination of the chemical composition of stellar atmospheres, which requires the highest possible resolving power and dispersion in order to obtain definitive results.

Following the meetings, which were most valuable not only for the material presented but also for the opportunity to meet astronomers working in related fields of research and to discuss problems of mutual interest, the writer spent two days at the offices of the Mount Wilson Observatory and at the California Institute of Technology. Opportunity was given to talk with many members of the staff and to examine the excellent equipment. Probably the most important new instrument is the direct-intensity microphotometer which Dr. Horace W. Babcock was kind enough to demonstrate. He has supervised the construction of the instrument, which is now nearly complete, and has added many features not available in other microphotometers. It is a null-type instrument where the blackness at any point on a stellar spectrum is balanced through photoelectric cells by a corre-

sponding point on the standard calibration spectrum and, as such, is very adaptable. It gives accurate results for plates differing greatly in density and the speed is adjustable to give maximum accuracy for either strong or weak lines. When completed, it promises to cut the labour of obtaining line-intensity measurements several fold and thus expand our fund of knowledge in this field very greatly. The writer was also given an opportunity to visit the laboratory of Dr. Robert B. King, who with his father, Dr. A. S. King, has studied spectra of very many atoms and molecules in the laboratory, and is now determining *f*-values, both relative and absolute, and thus intensities of lines produced by typical atoms and molecules.

We were also privileged to visit the Lick Observatory from July 8-11, and were accorded the gracious hospitality of Dr. and Mrs. C. D. Shane and other members of the staff. Many tales had been told of the tortuous trail from San Jose to Mount Hamilton but we were able to navigate the turns and follow the well-paved road without undue difficulty. Following dinner at the Director's residence on Thursday, we viewed the sunset over San Francisco Bay and noted the varying shapes taken by the solar disk as it sank into the haze above the Pacific Ocean. When it became dark, we spent some time with Dr. F. J. Neubauer at the 36-inch refractor and then were shown the operation of the 20-inch astrographic telescope. Dr. Shane allowed us to examine a few of the large 18-inch square plates taken with that instrument. The guiding is excellent and the stars appear as round points to the very edge of the plate, while numerous faint nebulae can be seen in almost any region. The next night, being visitors' night, we observed Jupiter through the 36-inch refractor and then spent some time at the 36-inch Crossley reflector where Dr. N. U. Mayall was taking a spectrogram of the supernova in N.G.C. 6946 which he had recently discovered. Finally we visited the 12-inch refractor where Dr. Olin Eggen was observing the light variation of a 9th-magnitude, short period Cepheid with his photoelectric photometer. Just before leaving the Observatory on Saturday morning, Dr. Weaver showed us the prototype of his measuring machine which makes objective measurements of the positions of spectral lines on the photographic plate using a vibrating mirror and photoelectric cells.

Before leaving the "Bay" area, we spent an evening with Miss

Jean McDonald, who is now on leave from the Dominion Astrophysical Observatory and is taking summer courses at the University of California in Berkeley. She showed us the buildings of the astronomical department on the campus and also the view over the bay from the hills near Berkeley. Then, after a day in San Francisco, we continued up the coast of California and Oregon and returned to Victoria on July 17.

In all branches of science it is important that workers in each field meet to discuss matters of common interest. In astronomy, international co-operation has always been of the highest order and, in particular, Canadians have always been warmly welcomed at gatherings of American astronomers. Attendance at meetings such as have just concluded is especially valuable to those of us who live in Western Canada where the great distances preclude frequent visits by other astronomers. It is with a deep sense of appreciation that the writer records that the Department of Mines and Resources made it possible for him to attend these important astronomical conferences.

Dominion Astrophysical Observatory,
Victoria, British Columbia,
August, 1948.

THE "AMATEUR" ASTRONOMER

By Frank R. Vaughn

What do we mean when we use the word "amateur" to describe a person having an active interest (more especially, a *scientific* interest) in a particular field? To-day the word is often used in a slighting sense, to denote an individual superficial in his knowledge or experience of a subject. The meaning inherent in the word itself, of course, is only that that person derives no income from his activity in the field chosen for study, the implication being that he does it for the pleasure to be gained thereby, insofar as mental stimulation and the attainment of an improved cultural outlook may be considered such. Immediately we exclude such trivia as collecting matchbox covers, etc., as something quite different.

It is certain that in former times, "amateur" indicated real accomplishment in a field, for example Herschel, and reflected the greatest credit on the person so termed. The reason for the basic change in the usage of the word is probably purely cultural in nature, and not divorced from the greater tendency toward specialization and attention to minutiae with concurrent educational changes. A man must have to-day a much larger body of knowledge than formerly to cover the same *aspects* of his field. Thus, it is certainly more difficult to be a true "amateur" now, as outside activities in scientific fields are apt to require a larger amount of time for the attainment of proficiency than the bulk of men are able to "afford", though more of this later. An average hobbyist, with his limited (not slightingly used) intelligence and facilities, is likely to be on the order of a gadgeteer or dabbler, and those relatively few men *with* sufficient means and cultural background fall often into the ranks of the dilettante-type of intellectuals—really little more than *advanced* dabblers.

If one is to study a scientific field the choice narrows to one of two possibilities, assuming he has sufficient interest to *find* time for his avocation; first, he may cover a field in a general way, thus possibly conforming to the criterion for a "specialized philosopher"; or second, he may choose some particular facet of a subject, and pursue that facet intensively, becoming expert in that single study.

The concept of the "true amateur" is perhaps more nearly realized in the latter choice, though this certainly does not mean that one needs no background in other fields as well. It has been a rigid requirement of original thinking that one must have an ample store of seemingly unrelated facts and understandings in order to have material for co-ordinated thought. One can do no better than to cite an example from Baker's "Science and the Planned State" to illustrate this point.

The remedy for cancer of the prostate gland was gradually *evolved* from this series of discoveries: (1) the finding in the 17th century that the prostate of a castrated animal was deficient in size and secretion; (2) confirmation of the foregoing observation in man, in 1847; (3) a study of the relationships between the testis and prostate, in 1889 (in hedgehogs!); (4) the discovery in 1926 that injection of female hormone in male animals also caused decreased activity on the prostate; (5) the discovery in 1912 of two types of phosphatase in the lining membrane of the intestine, one being important in prostate function; (6) the discovery in 1938 that persons with cancer of the prostate have blood overly rich in the prostate-significant type of phosphatase, and that high concentrations of this form of the chemical in experiments produced the symptoms of prostatic carcinoma.

It is hardly necessary to go on to show how these lines of research were woven together, by yet another man, in such a way that a remedy was established. It is only important that the *final* discovery in this chain was made by a man who must have had a sufficient background in four different fields, each of which constitutes a life-work for many scientists. These fields are: biology, physiology, biochemistry, and pathology. It is not pretended that one man could be *specially* excellent in all these fields, but it is certain that he had a rather good grasp of developments and researches in other subjects than his own which *could* have valid relationships (though perhaps unknown at any given moment) to his own studies.

The idea is the same in any study we wish to make—we have only to substitute names. Thus, for say an astrophysicist, some pertinent background fields would be astronomy, physics, nuclear physics, mathematics, optics and chemistry. A general reading

background in philosophy and literature would be found helpful also. Of course, it is impossible to say from whence ideas may spring, so that relevant lists of knowledges necessary have little utility beyond indicating the fact that one who is not conversant with what is going on around him in *other* activities cannot achieve real soundness in his own work.

The most common complaint of would-be amateurs (possibly the 'quotes' may be now left off) is that time is lacking. This is perfectly justifiable if one assumes first that their interest was insufficient to begin with. I have not yet seen an amateur of ability who did not have time—who did not *find* time—to pursue his interest. Brashear (optics), Herschel, Perthes (geology) were of the greatest in their fields, and were also men who had uncommon demands upon their time for the mere earning of a living, at least in their earlier years. True, these are great exceptions, but one could perhaps do worse than to emulate them, if even to a lesser degree, for the *personal* values to be realized.

If a man carried on scientific work for many years, publishing nothing, he would not have worked in vain, for his own life would be that much better for having done so. Much more, of course, would have been gained by free intercourse with others, but that is not the point. Intellectual activity in itself is an end of the highest value.

Discussion of the titled point of this essay, which is that of looking at the amateur astronomer, has been delayed with a view to suggesting an idea or two concerning the intrinsic worthwhileness of his activity, in order to see more objectively an ideal framework within which the writer thinks amateur astronomy falls.

A doubt one often hears from an amateur is to the effect that he feels he can contribute little to his field. The writer thinks this an unnecessary and even meaningless doubt, which has already been overcome by the mere fact of his working in a field he enjoys. His contribution to himself is certainly not the least value of his work. Can one discount the value of his contacts with other amateurs, especially young ones, whom he is assisting along the same intellectual road with *possibly very great* end-results? The evaluation of the merit of amateur astronomy should perhaps be as simple as this: "I enjoy the activity; it gives me a sense of gain personally;

it is stimulating; I may be able to help someone else on the way (and incidentally gain thereby myself); and it is just possible, though not necessary, that I may be able to contribute something of value to the field I study."

Desultory observation of a few objects, with no particular end in view, is certainly not without some personal value to the individual whose mind thrives on the contemplation and understanding of the beauty of far places—the precision and hugeness of the heavens. A poet might call such a person "an amateur astronomer". We are here chiefly concerned with another type—the man who wants to "do something" requiring exercise of his brain, and having tangible results in the form of a co-ordinated idea of his subject during some particular period (as in the case of planetary study), with the idea of fitting it into a *larger* framework of time for its better intrinsic understanding.

An appeal is made to the reader, in view of the above, not to consider his avocation of amateur astronomy in the light of practical results, but rather to think of it as something of the greatest value by itself, without reference to the rather dull evaluations of everyday life.

540 W. Wellington,
Chicago, Illinois,
8 August, 1948.

WAVE-LENGTH STANDARDS FOR RADIAL-VELOCITY DETERMINATIONS, III. THE A-STARS WITH SINGLE-PRISM DISPERSION*

By R. M. Petrie

Abstract

Radial-velocity standards for single-prism spectra of A-type stars have been determined from one hundred and twenty-four spectrograms of twenty stars. The effective wave-lengths were predicted from high-dispersion spectra in conjunction with control velocities supplied by members of the *Taurus*, *Ursa Major* and *Coma* clusters and some visual binaries. The adopted standards reproduce the zero point previously determined from the solar system. As a by-product the radial velocities of twenty-one A stars are given.

Effective wave-lengths for radial-velocity determinations have been studied in two previous *Contributions*[1] and standards have been given for solar-type spectra and for the A stars (A0 to F2) with high dispersion. The work has now been extended to single-prism standards for the A stars and the results are presented in this paper. The methods adopted previously have been continued and the reader is referred to *Contribution* No. 4 for a fuller discussion.

The spectra studied range from A0 to F2 and include sharp- and diffuse-line objects. Two dispersions were used: first, a linear dispersion at Hγ of 30 A./mm. with a slit-width of .051 mm. and designated IM and, secondly, the IS instrument giving a dispersion of 51 A./mm. at Hγ used with a slit 0.076 mm. wide. The spectra are, therefore, typical of those commonly used in radial-velocity work with moderate dispersion.

It was anticipated that common set of effective wave-lengths would be valid for use with both instruments but this was found not to be the case. The lower purity and smaller scale of the IS spectrograms means that any spectral feature embraces a larger wave-length interval and thus the two instruments have to be considered separately. Our experience in this regard suggests that

[1] *J.R.A.S.C.*, vol. 40, p. 325, 1946; *Cont. Dom. Ap. O.*, No. 4, 1946; and *J.R.A.S.C.*, vol. 41, p. 311, 1947; *Cont. Dom. Ap. O.*, No. 10, 1948.

Contributions from the Dominion Astrophysical Observatory No. 11

it is unwise to adopt a set of effective wave-lengths for any spectrograph until it has been verified, line by line, by several control stars having well-determined velocities.

The control objects, for IM and IS are listed in Table I. These stars are members of the *Taurus*, *Ursa Major* and *Coma* moving clusters and A-type components of visual binaries. As before we adopt 43.1 km./sec. as the motion of the *Taurus* cluster; 19.1 km./sec. for the *Ursa Major* cluster and −0.4 km./sec. as the radial velocity of the *Coma* stars. The adopted velocities for the solar-type components of visual binaries are taken from Lick III-prism, and Victoria IIL, determinations. For the stars H.D. 95418, 116657 and 113139 in the constellation *Ursa Major* high-dispersion radial velocities were employed as controls in preference to the calculated motions since it is known that the radial velocities of these stars deviate from the cluster motion.

The method of determining the effective wave-length of a blend so that it is largely independent of the radial-velocity measures has been described in the earlier papers[1] and was followed in the present case. The relative intensities of the contributing lines were taken from the *Revised Rowland Table* and from high-dispersion studies of several A- and F-type stars. The spectra of *Sirius* and γ *Geminorum*[2], α^2 *Canum Venaticorum*[3], α *Cygni*[4], α *Carinae*[5], *Procyon*[6] and β *Coronae Borealis*[7] were consulted for these data. Except in a few cases it was possible to predict the effective wave-length from the relative intensities of the component lines as estimated upon high-dispersion spectra. The success of the prediction was established by comparing the measured velocity with the adopted control velocity but, apart from the exceptions noted above, the measured velocities were not used to adjust the predicted wave-lengths. A few empirical wave-lengths were tolerated; they are for features found to be reliable over a substantial spectral range

---

[2]L. H. Aller, *Ap. J.*, vol. 96, p. 321, 1942.
[3]O. Struve, *Ap. J.*, vol. 98, p. 361, 1943.
[4]O. Struve, *Ap. J.*, vol. 94, p. 344, 1941.
[5]J. L. Greenstein, *Ap. J.*, vol. 95, p. 161, 1942.
[6]J. W. Swensson, *Ap. J.*, vol. 103, p. 207, 1946.
[7]W. A. Hiltner, *Ap. J.*, vol. 102, p. 438, 1945.
[8]*Publ. Lick. Obs.*, vol. 18, 1932.

TABLE I.—CONTROL STARS FOR SINGLE-PRISM STANDARDS

Star	Type	Instrument	Star	Type	Instrument
H.D. 25570	F2	IM, IS	H.D. 95418	A0	IS
27176	A8n	IM	108486	A3	IM
27819	A6n	IS	109307	A2	IM
27934	A3	IM, IS	109510	A3	IM
27962	A3s	IM, IS	113139	F0	IS
28527	A8	IM	116657	A8	IM, IS
28546	F0s	IM, IS	118022	A3	IM
30210	A2	IM	137391	F0	IM, IS
40183	A2	IM, IS	209790	A3	IM
48915	A1s	IM	222603	A5	IM, IS

but for which the predictions fail, usually because of the multiplicity of the blending lines. Every effort was made to keep the calculated wave-lengths free from bias so that instrumental errors, errors of measurement, etc., would not affect them. Solar wave-lengths were used as in the previous study.

The adopted wave-lengths are listed in Table II which gives in addition the principal contributors to the blend, and the spectral intervals over which the wave-lengths are found to be reliable. The second column indicates the derivation of the blended feature; ⊙ means that the wave-length as listed in the solar table is adopted, ⊙,* means that the solar wave-lengths of the blending lines are combined according to their estimated intensities in A-type spectra. The letter *a* signifies that an adjusted wave-length is adopted to conform to the radial velocities of the control stars. The values in Table II were adopted after studying the measures of seventy spectrograms (17 stars) with IM dispersion and fifty-four spectrograms (11 stars) with IS dispersion.

A large initial list of spectral features was measured but the analysis eliminated all but those in Table II. It may be considered that this list is not sufficiently extensive since there are but twenty-two lines in all for the IM dispersion and only eighteen for the IS spectra. The radial velocities provide the answer to this question. The probable error of a single plate, derived from the internal agreement among the lines, is found to be ±1.2 km./sec. whereas that computed from the individual plate velocities is ±1.6 km./sec.

TABLE II.—SINGLE-PRISM STANDARDS FOR RADIAL-VELOCITY DETERMINATIONS OF A-TYPE STARS

λ I.A.		Valid Spectral Interval	Identification	Dispersion
3933.684	⊙	A0 - F2	Ca II	IM, IS
56.594	⊙, *	A0 - A8	Fe I, Ti I, Ca I	IS
56.639	*a*	A0 - F2	Fe I, Ti I, Ca I	IM
68.494	⊙	A0 - A3	Ca II	IM, IS
70.078	⊙	"	H ε	IM, IS
4024.784	⊙, *	A0 - F2	Fe I, Fe II, Ti II	IM
30.540	⊙, *	"	Mn I, Fe I, Cr II	IS
30.615	⊙, *	"	Mn I, Fe I	IM
45.667	⊙, *	"	Fe I, Zr II, Mn I	IS
45.796	⊙, *	"	Fe I, Zr II	IM
63.416	⊙, *	"	Fe I, Fe I	IS
63.555	⊙, *	"	Fe I, Cr II	IM
71.546	⊙	"	Fe I, Fe I, Cr II	IS
71.687	⊙, *	A3 - F2	Fe I, Fe I	IM
4101.750	⊙	A0 - F2	H δ	IM ,IS
4215.600	⊙, *	A0 - A8	Sr II, Cr II, Fe I	IM, IS
33.312	⊙, *	A0 - F2	Fe II, Fe I, Cr II	IM, IS
50.510	⊙, *	"	Fe I, Fe I	IM, IS
71.542	⊙, *	"	Fe I, Fe I	IM
71.562	⊙, *	"	Fe I, Fe I	IS
4307.914	⊙	"	Fe I	IM
40.477	⊙	"	H γ	IS
40.526	*a*	"	H γ	IM
4404.726	⊙, *	"	Fe I, Fe I	IM
81.241	⊙	A0 - A8	Mg II, Cr II, Fe II	IS
81.293	⊙, *	"	Mg II, Cr II, Fe II	IM
4501.280	⊙	A5 - F2	Ti II	IM
34.018	⊙, *	A0 - A6	Ti II, Fe II	IM, IS
49.560	⊙, *	A3 - F2	Fe II, Ti II	IS
49.600	⊙	A0 - F2	Ti II, Fe II	IM
4861.344	⊙	A0 - A3	H β	IM, IS

The precision given by our list of lines is, therefore, greater than the spectra will support because of other sources of error and so we do not require an extension to the list in Table II. Indeed the addition of lines of lower reliability would be a very dubious advantage. The above numerical values refer to IM dispersion but a similar argument is found to hold for the IS plates.

The radial velocities obtained from the wave-lengths of Table II are compared with the adopted control velocities for the clusters and visual binaries in Table III. The residuals are considered to be very satisfactory for single-prism spectra and are taken as

TABLE III.—TEST OF SINGLE-PRISM VELOCITIES

Control Group	IM Dispersion			IS Dispersion		
	Residual	Stars	Plates	Residual	Stars	Plates
	km./sec.			km./sec.		
Taurus Cluster	$+0.2 \pm 0.3$	7	33	$+0.2 \pm 0.3$	5	24
Ursa Major Cluster	-1.3 ± 0.6	5	21	-1.2 ± 0.3	5	24
Coma Cluster	-0.3 ± 1.1	4	16			
Visual Binaries	-0.3 ± 0.8	3	12	-0.1 ± 1.2	1	6
Mean Residuals	-0.4 ± 0.2			-0.5 ± 0.3		

evidence that the predicted wave-lengths retain, for the A stars, the zero point originally fixed by the solar system velocities. It is noted that the residuals are effectively zero for the *Taurus* stars, which group has the best determined velocity, and it is perhaps significant that the only appreciable residuals occur for the *Ursa Major* stars where definite variations from the cluster motion have been found.

A further important comparison can be made with velocities determined with high dispersion at the Lick Observatory and published in the *General Catalogue of Radial Velocities*.[8] We have for stars observed in common:

IM—Lick III-Prism = -0.1 km./sec. ± 0.4 (14 stars).

IS—Lick III-Prism = -0.7 km./sec. ± 0.4 (10 stars).

Further comparison may be made with the Victoria high-dispersion values as given in the previous study[1]. For stars observed in common we have:

IM—IIL = -0.5 km./sec. ± 0.5 (11 stars).

IS—IIL = -0.3 km./sec. ± 0.4 (10 stars).

[8] *Publ. Lick. Obs.*, vol. 18, 1932.

TABLE IV.—SINGLE-PRISM RADIAL VELOCITIES OF TWENTY-ONE STARS

Star H.D.No.		Type	Observed Velocity	Inst.	Plates	Remarks
25570		F2s	+ 36.7 ± 0.6	IM, IS	11	*Tau.* Cl.
27176		A8n	+ 35.7 ± 1.3	IM	4	"
27819		A6n	+ 39.5 ± 1.7	IS	5	"
27934	κ^1 *Tauri*	A3	+ 37.8 ± 0.3	IM, IS	8	"
27962		A3s	+ 38.2 ± 0.5	IM, IS	10	"
28527		A8	+ 40.6 ± 0.8	IM	5	"
28546		F0	+ 39.8 ± 0.8	IM, IS	9	"
30210		A2	+ 39.2 ± 1.1	IM	5	"
40183	β *Aurigae*	A2	− 17.3 ± 0.7	IM, IS	10	*U. Ma.* Cl.
95418	β *Urs. Maj.*	A0	− 12.6 ± 1.2	IS	4	"
108486		A3	+ 0.7 ± 1.1	IM	3	*Coma* Cl.
109307		A2	+ 2.7 ± 0.8	IM	4	"
107966		A2	− 4.3 ± 0.4	IM	4	"
108662		A0p	− 3.4 ± 0.3	IM	3	"
109510		A3	+ 4.0 ± 1.2	IM	4	Vis. Bin.
113139		F0	− 9.5 ± 1.9	IS	5	*U. Ma.*Cl.
116657	ξ^1 *Urs.Maj.*B	A8	− 13.4 ± 0.7	IM, IS	9	"
118022	78 *Virginis*	A3	− 8.4 ± 0.7	IM	4	"
137391	μ*Bootis* A	F0	− 7.6 ± 1.0	IM, IS	9	Vis. Bin.
209790	ξ*Cephei* A	A3	− 9.5 ± 1.8	IM	5	"
222603	λ*Piscium*	A5	+ 9.4 ± 1.1	IM, IS	9	*U. Ma.* Cl.

It is concluded from these comparisons that the single-prism velocities with the wave-lengths of Table II are sensibly free from systematic error. Comparisons will be continued and systematic corrections will be derived if they are found to exist. It seems safe to predict that any correction so found will be less than 1 km./sec.

The effective wave-lengths of Table II have been adopted at Victoria and will be used henceforth in all single-prism radial velocities of the A stars unless otherwise mentioned specifically.

As a consequence of this study radial velocities have been determined for twenty-one stars. These are listed in Table IV, the various entries requiring no description. Where IM and IS results are combined the latter are given half weight in forming the mean value. The velocities in Table IV merely strengthen and supplement previous determinations since all the stars have been observed before for radial velocity.

Dominion Astrophysical Observatory
Victoria, B.C.
January, 1948.

WAVE-LENGTH STANDARDS FOR RADIAL-VELOCITY DETERMINATIONS, IV.*

THE SOLAR-TYPE STARS WITH LOW DISPERSION

By JEAN K. McDONALD

ABSTRACT

A list of effective wave-lengths for radial-velocity determinations from low-dispersion spectrograms (51 A./mm. at Hγ) is presented for solar-type stars (F4-K8). The final selection of 19 reliable wave-length standards is based upon a line-by-line study of measures of 79 spectrograms of the sky, the moon, Mars and eleven standard velocity stars, in conjunction with the solar wave-lengths of the *Revised Rowland Tables*. Radial velocities of the eleven stars determined from the adopted wave-lengths show the following satisfactory agreement with the corresponding standard velocities and the Lick three-prism determinations:

Victoria minus Standard: − 0.2 km./sec. + 0.1 (73 plates)
Victoria minus Lick: 0.0 km./sec. + 0.1 (66 plates)

* * * * *

This is the fourth paper in a series presenting the lists of revised wave-lengths to be used henceforth in radial-velocity determinations at this Observatory. The reader is referred to the first paper of the series[1] for a discussion of the problem of determining for each spectral class radial-velocity wave-length standards which are related to one fundamental system and which are homogeneous throughout all the spectral classes.

Three earlier Contributions have given the wave-length standards determined for solar-type stars (F4—K8) for moderate and for high dispersion;[1] for A stars (A0—F2) for high disperion;[2] and for A stars for moderate and for low dispersion.[3] This paper extends the study to the spectra of solar-type stars (F4—K8) obtained with low dispersion, making use of the spectrograph arrangement designated *IS*, which gives a linear dispersion of 51 A./mm. at Hγ. The slit width used for most of the spectrograms was 0.076 mm.

---

[1] *J.R.A.S.C.*, vol. 40, p. 325, 1946; *Cont. Dom. Ap. O.*, No. 4, 1946.
[2] *J.R.A.S.C.*, vol. 41, p. 311, 1947; *Cont. Dom. Ap. O.*, No. 10, 1947.
[3] *Cont. Dom. Ap. O.*, No. 11, 1948 (in press).
* *Contributions from the Dominion Astrophysical Observatory*, No. 12.

The method adopted in Contribution No. 4 for solar-type stars with high and moderate dispersion was continued for the low-dispersion spectra. The original list of lines to be considered numbered fifty, and as many of these lines as could be detected were measured on 73 spectrograms of the eleven standard velocity stars shown in Table II, and on 6 spectrograms of the sky, the moon and Mars. The velocity residuals (measured velocity minus standard or computed velocity) were obtained for each line, and the mean velocity residual for each star, line by line, was plotted against spectral type. Those lines which showed a large variation throughout the spectral interval, F4—K8, were rejected immediately. Those lines which showed a large variation for a portion of the spectral interval were rejected for that portion only, and retained for the remainder of the interval. For example, the line λ4063.62 was rejected for all spectral classes and the line λ4340.44 adopted for the restricted interval F4—G5, on the basis of the following velocity residuals:

Spectrum	λ*4063.62*	λ*4340.44*
F5	− 6.4 km./sec.	+ 1.5 km./sec.
G0	− 2.0 "	+ 0.6 "
G5	+ 5.2 "	− 1.8 "
G7	− 2.0 "	− 5.5 "
K0	+ 4.2 "	+ 9.7 "
K1	+ 10.8 "	+ 5.5 "
K5	− 1.4 "	− 2.3 "
K8	− 1.5 "	− 6.0 "

Evidence of variation of a line with luminosity was briefly mentioned in Contribution No. 4. It is of interest to note that absolute magnitude effects appear to have influenced the measured positions of the features at λ4314.68 and λ4325.64 in the spectro-

Spectrum	λ*4314.68*	λ*4325.64*
F5 (α *Persei*)	− 10.0 km./sec.	− 8.9 km./sec.
F5 (H.D. 89449)	+ 0.4 "	+ 3.9 "
G0	+ 2.8 "	+ 2.4 "
G5	− 1.0 "	+ 0.6 "
G7	+ 4.2 "	+ 0.6 "
K0	− 2.0 "	
K1	− 0.1 "	
K5	− 2.6 "	
K8	− 1.9 "	

grams of the supergiant α Persei. The velocity residuals are given for the spectral intervals over which the lines are considered reliable.

In each of these cases, a line due to ionized scandium lies on the the violet edge of the group of lines considered to be contributing to the measured feature. We should expect its influence in determining the mean position of the blended feature to be greatest in the supergiant, where an ionized metal tends to be strong, and the measured velocity residuals for α Persei confirm this effect. It would appear to be important in determining the radial velocity of a supergiant star to consider carefully any blended line where one of the contributors to the line is an ionized metal known to be sensitive to absolute magnitude effects, and to reject the measure of such line if it shows a large variation from plate velocity.

The variable features having been rejected, the remaining lines were then studied individually in order to select from the solar wave-lengths of the *Revised Rowland Tables* the line which represented the feature measured on the spectrograms. Where more than one line contributed to a blend, every effort was made to interpret the measured features in terms of the weighted mean of the Rowland solar wave-lengths of the lines considered, in view of the dispersion, to contribute to the blended feature. It should be emphasized that the measured position of each of the individual or blended lines was used as a guide only, in determining the effective stellar wave-length. The method does not involve arbitrary adjustment of the Rowland wave-lengths in order to produce the stellar velocities. The line, or blend of lines, having been identified with some certainty, there still remained mean velocity residuals for an individual line as large as 3 km./sec., with a mean residual for all lines of $-$ 0.2 km./sec. $\pm$ 0.2. Only with reluctance were the blends of four of the lines considered impossible of prediction, and for these lines empirical wave-lengths were assigned which reduced the mean velocity residual to zero.

Table I contains the final adopted wave-lengths, the spectral range over which such wave-lengths are reliable, and the identification of the principal elements contributing to the line. The symbols in the second column, following Petrie's definitions, indi-

cate the origin of the adopted wave-length. ⊙ indicates that the solar wave-length given in the *Revised Rowland Tables* has been adopted. *m* indicates that a blend of more than one Rowland solar wave-length, weighted according to the Rowland intensities, represents the measured feature. *a* indicates that it was found necessary to choose arbitrarily a wave-length which would produce the measured feature. It might be noted again that only in the latter case were the measured positions of the line used, other than as a guide, in determining the effective wave-lengths.

TABLE I. Effective Wave-Lengths for Radial-Velocity Determinations of Solar-Type Stars, with Low Dispersion (*IS*)

λ I.A.		Valid Spectral Interval	Identification
3961.537	⊙	F4—K8	Al I
4005.244	m	K0—K8	Fe I
4030.645	m	G0—K8	Fe I, Ti I, Mn I
4034.494	⊙	K0—K8	Mn I
4045.765	m	F4—K8	Fe I, Co I
4071.738	m	F4—K8	Fe I
4092.478	m	G0—K8	Fe I, Mn I, Ca I
4132.230	a	F4—K8	Fe I
4215.686	a	F4—K0	Fe I, Sr II
4254.348	⊙	F4—K8	Cr I
4260.488	⊙	K0—K8	Fe I
4307.994	m	F4—G5	Fe I, Ti I, Ca I
4314.683	m	F4—K8	Fe I, Sc II, Ti II
4325.635	a	F4—G7	Fe I, Sc II
4340.441	a	F4—G5	Hγ
4404.745	m	F4—K8	Fe I, Ti I
4415.137	⊙	F4—K8	Fe I
4461.810	m	G5—K8	Fe I
4482.214	m	G5—K8	Fe I

It is of interest to note that the reduction of the list of reliable lines to 19 does not affect the reliability of the measures, since the probable error of an average plate from the agreement of its individual lines is only ± 1.0 km./sec. as compared with ± 1.9 km./sec., the probable error of an average plate from the agreement with other plates of the same star. The greater source of error,

therefore, would appear to be not in accidental errors of measurement but in faults inherent in the plate itself and outside the control of the measurer, due, for example, to instrumental defects, guiding, etc., and to increase the number of lines measured would not reduce this source of error.

TABLE II. Radial-Velocity Residuals Using Revised Wave-Length Standards (*IS*)

Star	Spectrum	Plates	Victoria − Standard km./sec.	Victoria − Lick km./sec.	Victoria *IS* − Victoria *IM, IIL* km./sec.
H.D. 89449	F5	8	− 0.3 ± 1.0	+ 0.1 ± 1.0	
α Persei	F5	6	− 0.8 ± 0.5	− 1.1 ± 0.5	− 0.7 ± 0.4
o Aquilae	G0	6	+ 0.5 ± 0.7	− 0.7 ± 0.7	
κ' Herculis	G5	8	− 1.2 ± 0.8	− 1.0 ± 0.8	− 1.8 ± 0.9
H.D. 76294	G5	10	0.0 ± 0.8	− 0.1 ± 0.8	
H.D. 65583	G7	7	− 0.9 ± 1.2		
α Bootis	K0	6	− 0.3 ± 0.7	0.0 ± 0.7	− 0.1 ± 0.7
β Geminorum	K0	4	+ 1.0 ± 0.7	+ 0.7 ± 0.7	
H.D. 26162	K1	6	+ 1.0 ± 1.0	+ 2.6 ± 1.2	
μ Piscium	K5	6	− 0.2 ± 0.8	+ 0.8 ± 0.9	
α Tauri	K8	6	+ 0.2 ± 0.4	− 0.6 ± 0.4	+ 0.3 ± 0.4

The velocities of the standard objects were derived from the adopted wave-lengths, and Table II contains, for each star, a comparison with its velocity as given in the General Catalogue, and as published for the Lick three-prism spectra. A comparison is also available for the four stars whose velocities were determined by Dr. Petrie from his adopted wave-lengths for high and moderate dispersion.

For the eleven standard velocity stars, the mean velocity residuals are:

Victoria *IS* minus Standard: − 0.2 km./sec. + 0.1 (73 plates)
Victoria *IS* minus Lick three-prism: 0.0 km./sec. + 0.1 (66 plates)
Victoria *IS* minus Victoria *IM, IIL:* − 0.6 km./sec. + 0.3 (26 plates)

All Victoria radial velocities determined from spectra obtained with the single-prism short-focus arrangement of the spectrograph (*IS*) for spectral types F4—K8 will be based, henceforth, upon the wave-length standards given in Table I.

It remains now to extend the study of radial-velocity standards to stars of spectral classes O and B. It is intended that this should be done by securing spectra of O and B stars known to be members of moving clusters whose space motions are known or can be determined, and by securing spectra of O and B stars known to be components of visual binary systems, where the other component is of a spectral class for which radial-velocity standards have been determined. Consideration is now being given to the difficult problem of finding suitable objects in these two groups.

Dominion Astrophysical Observatory,
Victoria, B.C.
March 31, 1948.

A NEW PROJECTION INSTRUMENT FOR THE RAPID DETERMINATION OF STELLAR RADIAL VELOCITIES*

By R. M. Petrie and S.S. Girling

(With plates VI, VII)

Abstract

The paper describes the design and operation of a projection comparator which reduces the time of measurement of a stellar spectrogram for radial velocity. The "reduction" of the plate to a standard dispersion and the recording of the comparison line readings are eliminated by optical and mechanical features of the new instrument. Tests and comparisons show that the new method is not inferior in accuracy, while a substantial saving is effected in the time necessary to obtain a velocity.

The laborious and time-consuming nature of accurate radial-velocity work is too well known to require extensive comment. Three spectrograms at least must be measured to obtain a reliable value for a single star. The measurement of each spectrogram involves the setting of the micrometer, and the reading of the head, about two hundred times. Even then the task is but half completed since the "reduction" of the measure, a process of interpolation, demands considerable computation. Nor should it be overlooked that, in the many arithmetical operations, the chance of errors being committed is not negligible. It is readily seen that any extensive program of radial-velocity determinations is extremely time-consuming.

The need to expedite this branch of the work at Victoria has been felt for some time since several major programs are in progress. A few years ago[1] an advance was made by replacing the conventional visual microscope by an all-projection system. The change reduced the fatigue produced by the long-continued use of a visual microscope and thus expedited the measurement of the spectrograms, but it did not reduce the number of readings nor shorten the subsequent computations. In order further to facilitate our work it was proposed that some of the above-mentioned steps be eliminated by causing them to be performed by mechanical and optical means so

*Contributions from the Dominion Astrophysical Observatory, No. 13.

[1] *J.R.A.S.C.*, vol. 31, p. 289, 1937.

that the only measurements to be made and recorded would be the velocity displacements themselves. This, incidentally, is a goal which has been partly achieved in the Hartmann Spectrocomparator.[2] Preliminary trials with an experimental model were made and reported in 1945.[3] The results were so encouraging that a machine was designed and constructed in the Observatory workshop and is now available for routine radial-velocity measurement. This article is prepared in order to give some account of the design of the new machine, which we shall call the Projection Comparator, and to report on the results obtained with it so far.

The new machine is an all-projection instrument avoiding the use of visual microscopes entirely. A highly magnified image of the spectrogram is projected upon a screen where it is examined and measured. The plate is mounted upon the turntable of a conventional micrometer with an accurate screw of ½ mm. pitch and a micrometer head divided into 500 parts. The viewing screen however is not the usual fixed surface with a ruled reticle but is a scale upon which are ruled the positions of the lines of the comparison spectrum and also those of the stellar lines corresponding to plate velocity zero. The projected image is matched in size precisely to that of the ruled scale and the projected comparison lines are set exactly upon the ruled comparison lines of the scale. When this is done the velocity displacements of the (projected) stellar lines, with respect to their ruled zero positions, are seen at once and may be measured directly with the micrometer. The measured displacement is then converted into radial velocity by a simple multiplication by the the *rVs* (km. per second per scale unit) factor.

The Micrometer

The disposition of the parts of the machine may be seen in the accompanying photograph, Plate VI. The micrometer *M*, from a standard measuring machine, is firmly attached by screws to the massive casting *C*, which supports all parts of the machine. A turntable has been added to the usual stage to facilitate the proper aligning of the plate and to do away with the necessity for removing

[2] *A.N.*, vol. 155, No. 3703, 1901.

[3] *Ast. Jour.*, vol. 52, p. 48, 1946; *Sky and Telescope*, vol. 5, No. 6, p. 12, 1946.

the plate for reversal. At the left-hand end of the carriage a micrometer screw *S* provides a slow motion of the plate independent of the main measuring screw. This is used for producing coincidences between the projected comparison lines and the corresponding rulings. The usual micrometer head *H* has been replaced by one reading from 0 to − 0.500 and from 0 to + 0.500 instead of one divided from 0 to 1.000. Thus negative, as well as positive, displacements are read directly, eliminating the need for mental subtraction when recording the setting. The micrometer-head readings are projected on a viewing screen *R*, magnified five times, where they are easily read directly.

The Projection System

The projection system is composed of a lens in a micrometer focussing mount *L* and two plane mirrors *m*, aluminized upon their front surfaces and carried upon the horizontal arm *A*. The mirrors are fixed at a 45° angle to the horizontal and may be rotated for adjustment about the arm *A*. The horizontal arm is supported from the vertical post *P*, which is securely fastened to the base casting. It may be clamped at any position upon the vertical post and when so clamped may be moved slowly through a range of 20 cms. by means of the crank *B* and screw *J*. The magnification of the projected image of the spectrogram may be varied by a vertical movement of the mirrors from 25 to 70 diameters while the slow motion allows one to change the magnification to any precise value for the exact matching with the ruled scale.

The projection lens was selected upon the advice of Dr. James Baker, whose assistance and co-operation were most helpful, and was supplied by the Perkin-Elmer Corporation. The projection lens must have certain properties if full advantage is to be taken of the labour-saving features of the new machine. A relatively long stretch of spectrum, about 4 mm., must be projected in good definition and with a constant magnification over the projected image. Since the magnification used varies up to some sixty diameters, it is obvious for practical reasons that the lens must be of short focal length and hence must cover a considerable angular field. The lens as supplied has a focal length of 7/8 inch and, at

full aperture, works at f:2. In practice it is stopped to approximately f:4. The lens performs well giving excellent definition over a good field and is satisfactorily free from distortion. The illumination of the plate is provided by a 250-watt projection bulb some distance from the machine; the light is concentrated upon the plate by mirrors and condensing lenses through holes in the casting *C* and the micrometer.

The Scale Carrier

As mentioned above, the projected spectrogram image falls upon a paper screen upon which are ruled the positions of the stellar and comparison lines. This screen takes the form of a long paper scale which is wound upon, and passes between, the rollers on the aluminum scale carrier *T*. The paper scale is held under constant tension at all parts of its travel and moves smoothly from one part of the "spectrum" to another. The rollers are actuated by a crank which may be clamped when in any set measuring position. The scale carrier sits upon the heavy base, being located by two dowel pins entering into the base. It is lifted and reversed when the spectrogram is reversed.

The Paper Scales

The production of the paper scales was in some respects the most difficult task confronting us. The problem was to rule precisely the positions of several dozen comparison and stellar lines. Despite the high magnification of the projected image of the spectrum (63.5x) it is essential that the rulings be very accurately drawn; an error of 0".001 between the drawn comparison and stellar lines amounts to an error of 1.4 km./sec. with moderate dispersion (*IS*) and to 0.5 km./sec. with high dispersion (*IIL*), so that no appreciable error can be tolerated in the scales. A special table was made for holding and moving the paper with feed, and take-up, spools and devices for aligning the paper and holding it securely during the ruling. This table was clamped to the slotted table of the milling machine, and settings were made on the dial of the longitudinal feed screw, which reads directly to 0".001. The ruling was performed by moving the paper and table bodily under the

pen by means of the cross-feed. Automatic guides raised and lowered the pen so that the ruled comparison and stellar lines were of the proper length and correctly positioned to match those in the projected image. Before being accepted each scale was carefully tested to ensure that errors were avoided during the process of ruling. The stellar lines are ruled for the wave-lengths adopted in our standard radial-velocity reduction tables, thus maintaining the system of our velocities.

Operation

The appearance of the viewing screen is shown in Plate VII which also shows the projected micrometer-head reading. In operation the machine is convenient and quite easy to manipulate. The spectrogram having been placed upon the turntable and the appropriate scale having been selected and placed in the carrier, the operator then adjusts the plane mirrors until the projected image matches exactly the scale of the ruled comparison lines. This adjustment is, in essence, the elimination of the "reduction curve" between the plate and the standard table. The operator next brings the first section of the spectrum to be measured into the centre of the field by quick motion of a carriage under the turntable and also centers the same section of the ruled scale. The micrometer screw S is now used to make *exact* coincidence between the projected comparison lines and the corresponding rulings. This step is equivalent to the measurement of the comparison lines although readings are neither made nor recorded. Having set upon the comparison lines the operator now uses the micrometer head H, which has remained at zero during the foregoing steps, and sets upon the stellar line, bisecting it with its corresponding ruled line. He then reads the velocity displacement, positive or negative, upon the micrometer head. This is the only reading which is made and recorded. After measuring all the stellar lines which appear in the field (with one setting on the comparison line) the plate and scale are moved to the next section and the process is repeated until the plate is measured. Plate and scale are then reversed and the measurement is made in the reverse direction. All that remains is to multiply the recorded displacements by the proper factors and the plate velocity is obtained. It is seen then that the new machine

eliminates the measurement of individual comparison lines, the determination of the reduction curve, and its application to the settings on the stellar lines to compute velocity displacements from the standard table. It may be noted that while applying some of the principles of the Hartmann Spectrocomparator this instrument preserves the individual line velocity as in the standard micrometer measures.

Performance

The projection comparator has been in use for a relatively short time but the performance has been satisfactory and no serious weaknesses have yet been revealed. A comparison of radial velocity results is made in the accompanying tabulation. The velocity differences in column three are quite acceptable and demonstrate that serious systematic errors have been avoided in preparing the scales. It is felt that the velocities with the new machine are substantially as reliable as those derived by the more fundamental direct micrometer method; however comparisons will be continued throughout the "life" of each scale in order to determine whether small systematic corrections are to be applied.

Comparison of Results with New and Old Machines

Spectral Types	Dispersion	Radial Velocity Differences		Measurement Error
		New−Old	No. Plates	New/Old
		km./sec.		
F—G—K	High; 11 A./mm.	− 0.2 ± 0.2	11	1.5
A—F	" "	+ 0.4 ± 0.4	10	1.2
B	" "	+ 0.2 ± 0.3	6	1.0
F—G—K	Moderate; 30 A./mm.	− 0.2 ± 0.2	25	1.2
A—F	" "	− 0.6 ± 0.4	10	0.8
B	" "	− 0.1 ± 0.7	14	0.9
F—G—K	Low; 51 A./mm.	+ 1.0 ± 0.4	22	0.8
A—F	" "	+ 0.6 ± 0.6	10	0.8
B	" "	− 0.9 ± 0.9	16	0.8

The error of measurement as judged by the probable errors of plate velocities is much the same in the two methods. This is shown

by the entries in column five of the table which are in the sense *p.e.* (new machine) divided by *p.e.* (micrometer).

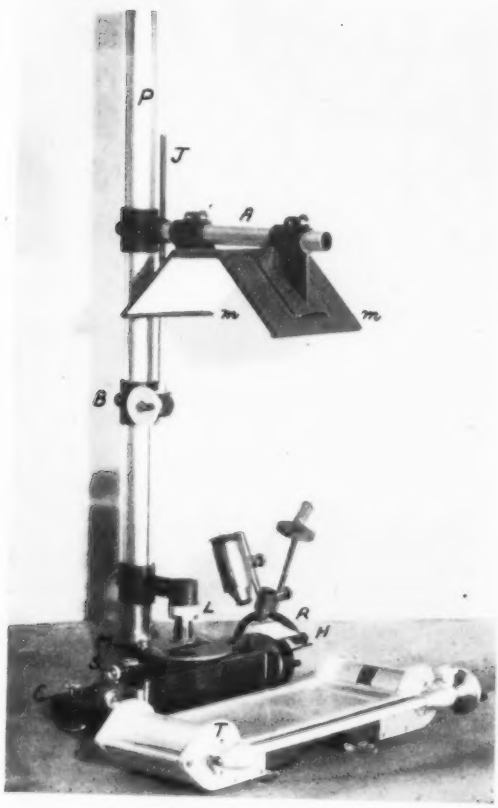
It is too early to give a firm value to the saving of time achieved by the use of the projection comparator; a substantial saving is well established however. A reckoning has been kept and it appears that the time required to measure and reduce a plate with the new machine is between one-half and two-thirds of that with the micrometer. The saving is greater with low dispersion since a larger fraction of the plate is included at one setting of the plate and scale. This aspect is of practical importance because the more extensive velocity programs are being pursued with lower dispersion as we go to fainter and fainter stars. The saving of time is expected to increase as one becomes more accustomed to the new technique and a further gain is anticipated from the use of specially-printed forms which reduce the recording and computing to a minimum.

The new machine has been found to be helpful in the examination of a spectrum for faint lines and lines perhaps not previously established as being present. If a scale is prepared with a number of possible stellar lines ruled in addition to the usual features, the search for the fainter lines is facilitated. The eye is directed to, and the attention is concentrated upon, the exact place where the line should appear and one can then search without the necessity for measuring a number of possible lines.

The chief criticism of the new method of measurement is that there is some danger of personal bias entering into the results. The operator is aware almost immediately of the velocity displacements being measured and some effort will be necessary in order to secure impersonal settings on the different spectral lines. It will be advisable, during the prosecution of a series of measurements, to check the results by remeasuring a few of the spetrograms by the conventional method.

In conclusion the writers wish to thank Dr. A. McKellar for assistance in ruling the scales and Miss J. K. McDonald for assistance in testing the accuracy of the ruled scales.

Dominion Astrophysical Observatory,
Victoria, B.C.,
April 5, 1948.



THE PROJECTION COMPARATOR

PLATE VII

THE PROJECTION COMPARATOR IN USE.

The photograph shows the projection of the stellar spectrograph upon the ruled scale and also the projection of the micrometer-head reading. The rulings on the scale have been made much bolder than normal for descriptive purposes. Note the displacement of the stellar lines (redward) with respect to the corresponding rulings.

WHY NORTH AT THE TOP?

By George Parson

THE reason why map-makers and cartographers place north at the top of their productions is a question which seems to have received less attention than it deserves. That it is purely an arbitrary choice, based on no compelling physical data, is not generally recognized. Since there is no north, south, east, or west in the illimitable cosmos, nor in any of its parts, except as we designate these directions for our convenience in establishing points of reference, it would be interesting to know what reasons, if any, caused the map-makers to decide on the practice now generally in vogue.

If the question be put to the map-makers themselves, the simplicity of their explanations will come as a shock to the inquirer, who will be told, for example, that the compass points north, and that the maker of maps merely follows the magnetic hint thus given. The map-maker seems to forget that according to the Chinese, who first discovered the loadstone, ages ago, the direction indicated by their magnetized floating needles was plainly south. We cannot say that they were wrong, for it is all in the point of view.

Had Chinese culture been more widespread—had the Orient exerted a greater influence on the scientific thought of the Occident—the probability is that south, instead of north, would now appear at the top of our maps. The Pole Star would then have indicated a southerly direction; Peary would have been the discoverer of the South Pole; Amundsen of the North; and geographical and astronomical nomenclature generally would have differed widely from that of to-day.

The directions indicated by the primitive compasses of the early days of serious map-making were undoubtedly not without influence in causing the makers of maps to adopt, eventually, the practice prevailing to-day. This came about largely from the importance of the Pole Star in navigation, and from the fact that the compass enabled navigators to fix the northerly direction when weather conditions made Polaris invisible. Notwithstanding all this, it is probable that reasons other than those relating to terrestrial magnetism weighed heavily with the map-makers in reaching a final decision.

That other reasons were considered during the long and tortuous history of map-making is shown by the fact that at one time the whole question seems to have been complicated by considerations which had a religious bias, rather than a scientific basis. Thus early medieval maps were drawn with the east on top, in veneration of the sacred places, a practice which gave us the word "orientation."

One of the principal reasons for the adoption of the present practice was in all likelihood based on certain known relationships between cold and *height*. Everyone knew that temperatures decreased with altitude above sea-level, and early in the history of the race it had been discovered that temperatures also decreased as one journeyed northward, and increased as one travelled toward the equator. We can readily understand that the map-makers, when once firmly impressed with these relationships between cold and height—height above sea-level, and especially height above the equator—would have come to regard the words "cold" and "height" as almost synonymous for map-making purposes, and would have begun to place the regions of extreme cold *highest* on their maps.

This whole provocative subject deserves further exploration and full documentary treatment. A complete study should take into account the fact that when map-making was in its infancy the centres of Occidental learning lay wholly in the northern hemisphere. Had they been situated a like distance south of the equator, say in South Africa, the chances are that analogous reasoning would have prompted the map-makers to place south in the position now occupied by north.

McLean, Virginia,
October 1, 1948.

ROCKETS AND SPACE TRAVEL

LETTER TO EDITOR FROM WILLY LEY WITH REMARKS BY J. W. CAMPBELL

Since you devoted a large part of the March-April Issue to the publication of a lecture by Prof. John W. Campbell in which my book "Rockets and Space Travel" is mentioned repeatedly, I hope that you will grant me some space for the purpose of clarifying and/or correcting some of the statements made by Professor Campbell.

First I would like to reply in short to the two quotations used by Prof. Campbell and published on p. 51 of the *Journal* issue mentioned. In the first of these two quotations Sir Harold Spencer Jones is stated to have expressed the thought that "the landing on a jagged surface such as the moon would almost certainly involve disaster". Now a rocket like the V-2 requires an area of not more than $2m^2$ for taking off. A spaceship built along the same principles but correspondingly larger might require an area of (generously estimated) 15 m^2 for a take-off. And since the ship would land in about the same manner as it takes off, namely by coming down tail first and braking the fall by the action of its rocket motor or motors, the area for landing would not have to be much larger than the area required for take-off.

I cannot imagine that Sir Harold would deny the existence of level and unobstructed and reasonably solid areas on the moon on the order of magnitude of 15 - 20 m^2.

As regards the quotation from Dr. F. R. Moulton's work I can only repeat what I said about it in my own book, namely that "the theory which would guide us through interplanetary space to another world" was published a full ten years before Dr. Moulton published this statement. As regards the quantities of food and water and oxygen required I can only point to the discussion in my book which shows that they are much smaller than one might think at first glance.

As regards the criticism of the turning mechanism given on page 57, I admit that the statement made in my book is somewhat misleading, because of an omission. I had intended to leave the statement that the turning is governed by the ratio of the masses involved as it stands in the body of the book for the lay reader and add the proper formulæ for the engineer and scientist in a "Note" in the appendix, just as other similar formulæ are given in "Notes" in the appendix. For reasons I don't recall anymore that "Note" dropped out during the printing, this shortcoming shall be remedied in subsequent editions.

Still, the analogy given on page 58 does not hold true because the method of turning the ship by a spinning wheel device in its interior is envisioned only for use on long trips where there is absolutely no hurry about putting the ship in the proper position. If a turning of the ship on short notice should be required it would, of course, be accomplished by using vanes in the exhaust blast. By means of such vanes—about which more will be said later—a ship could be turned through an angle of 90° in a very short time, it is quite possible that the maneuver could be accomplished in less than ten seconds.

The use of vanes in the exhaust blast has been contemplated for a long time. It was used experimentally for the first time by Prof. Dr. Robert H. Goddard in his rockets which ascended from the New Mexico desert in 1935 and which are pictured in his second Smithsonian Report (Miscell. Coll. XCV ; 1936). Dr. Goddard used this method in the form of vanes which were parallel to the blast and to the longitudinal axis of the rocket and which were forced (with their flat side) into the blast for corrections of the rocket's movement. The German research group at Peenemünde must have been acquainted with Dr. Goddard's method, but preferred to use graphite vanes which were in the blast all the time and which turned in the blast very much in the manner in which the rudder of a ship turns in the water.

The fact that a rocket can be steered and has been steered in thousands of cases (namely all V-2 rockets) by means of vanes in the exhaust blast, eliminates the whole argument on page 61. The ship is not "a car with accelerator but no brakes" but is perfectly capable of maneuvering. Therefore it would be capable of matching its velocity and direction of motion to the velocity and direction of motion of the station with a high degree of precision. Consequently no crash would result and no noticeable amount of momentum would be transferred from the ship to the station. (Needless to say that a station should be able to correct its orbit within narrow limits.) Take-off from the station would probably be accomplished by pushing the ship away, stern first, in some suitable manner (possibly compressed air in a piston arrangement) then letting the ship drift away for some distance and igniting its motor. Because of the steering by means of incidentally replaceable graphite vanes in the exhaust blast the ship will have no difficulty in "missing" the station when it accelerates under its own power.

I believe that these mistakes were caused by the fact that Prof. Campbell was insufficiently acquainted with the engineering detail of existing large rockets. This is also born out by the sentence on p. 66 where it is stated that "some of the rockets (V-2 rockets used at White Sands, New Mexico for high altitude exploration) exploded before reaching the earth on return". Fact is that the rockets, after some preliminary shots while the methodology of such shots was still under development, *were* exploded. Purposely. By means of T N T blocks inserted for this purpose. The reason is that the whole rocket buries itself too deeply in the desert sand for easy access and examination when permitted to remain in one piece. Hence explosion by means of T N T some 100,000 feet up on return because the resulting pieces, of irregular shape, arrive so slowly that they hardly are covered with sand and can be found easily.

Because of the possible utilization of vanes in the exhaust blast point (4) of Prof. Campbell's summary on page 68 is also invalid, although an engineer will naturally strive to have a line-up of ship and rocket motor which is good enough so that only a minimum of correction will be required.

Like Professor Campbell I do not believe that anybody will make a landing on the moon within the next ten years. But I do believe that the engineering fundamentals for such a feat are solved right now and that there is no need to wait for the discovery of new principles.

WILLY LEY

July 16, 1948
223 Rhode Island Ave., N.E.
Washington, 2, D.C.

REPLY TO THE ABOVE LETTER

Mr. Ley says in his fifth paragraph that his statement was misleading; that it was made for the lay reader, and that it was his intention to give a correct statement in a "Note". I think this is hardly fair to the lay reader. The statement was wrong in principle and was not even approximately correct in the case to which it was to be applied.

I cannot agree that Ley's argument invalidates the whole argument on page 61 of my paper. With vanes in the exhaust blast he could re-orient the rocket more readily, but (with the rocket he describes) he would still lack braking facilities when moving nose first. His final motion when entering a mooring socket would have to be nose first, and so it would be like approaching a curb in a car without brakes. Also, because V2 rockets have been guided to targets it does not follow that space rockets could be guided to moorings at a space station without crash.

A space station, to be of use, would have to be of considerable size. It could only control its orbital motion by the ejection of mass, and the larger it was the more matter would have to be ejected. The possibilities of orbit control appear remote.

The details of the difficulties of space travel could be elaborated greatly; I gave only a few examples.

J. W. CAMPBELL.

REVIEWS OF PUBLICATIONS

Astronomy, a text-book for Colleges, by William Lee Kennon, vii, 737 pages, 6¼ × 9⅛ in. Ginn and Co. 1948. Price $5.50.

At first sight of this massive three-pound book with a picture of an alidade among stars on the front cover, one's thought is that it might be similar to the attractive volumes by Guillemin and others often found on the centre table in the "parlour" two generations ago. But such is not the case. The book has modern chapter and page headings, and an abundance of rather large and bold diagrams, also of pictures of observatories and distinguished astronomers. Among the other illustrations one might mention "The zenith sun" (p. 95) and "Radar signals to and from the moon" (p. 147).

The main divisions of the book are: I. The apparent motions of the heavenly bodies and their geometrical representation, 200 pages; II. The solar system, 224 pages; III. The light of the stars, 196 pages; IV. The universe of stars, 60 pages. Then follow, a guide to the observation of the heavenly bodies (15 pp.), an appendix (9 pp.), an index (21 pp.) and lastly five star maps in a pocket.

The work is stated to be a text-book for Colleges, but the treatment is mostly elementary. A number of the formulae quoted are declared to be too difficult to be developed here, but three pages are used to deduce the ordinary formula for the Foucault pendulum. At the end of each of the thirty-one chapters there are (1) Exercises, (2) Topics for further study and reports, (3) References. The student may well be asked to solve numerical problems in order to fix in his mind some of the definitions and laws given in the text, but the "Topics" and some of the "Exercises" suggest high school discipline, and the "References" could reasonably be combined into a single list in the appendix.

It is evident that the author has laboured hard to make the book complete and logically precise, but the result seems to be an encyclopaedia rather than a text-book.

Errors in the spelling of proper names were noted on pages 31, 296, 395, 438, 446, 674.

C. A. C.

Nicolaus Copernicus, de Revolutionibus, Preface and Book I by J. F. Dobson and S. Brodetsky. 32 pages, 6½ × 10 in., portrait and 2 fac-similes. Royal Astronomical Society, Burlington House, London, W 1. 1947. Price 3s 6d.

The value of a knowledge of the history of science is being recognized more and more fully and several books devoted to this subject have appeared in recent years. There is special pleasure in reading the precise words of a founder of any branch of science.

The great book of Copernicus, "On the Revolutions of the Spheres of the Universe", was published in Latin in 1543. It is in six books and has an illuminating preface. In Book I Copernicus outlines his arguments for a moving earth and for placing the sun at the centre of our system. That constitutes the great change in mental outlook which is always associated with his name.

The translation is by the Emeritus Professor of Greek in the University of Bristol, assisted by the Professor of Mathematics in the University of Leeds, and it is in modern readable English. A biographical note and also notes to the translation are of special interest and value.

C. A. C.

Practical Astronomy, by George L. Hosmer. Fourth edition, revised and rewritten by James M. Robbins. 355 pages, 5½ × 8½ in. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd. 1948. Price $4.50.

This well-known text-book for engineering schools has been expanded and rewritten for this edition. It does not give derivations of all formulae but an appendix covers the spherical trigonometry required for such a course and the final formulae are given in convenient form. All explanations are given in words as well as by formulae, and a few historical references, such as the development of timepieces for longitude determinations, make the book very readable as well as informative.

Part I on "Fundamental Principles of Practical Astronomy" covers the celestial sphere, the astronomical triangle and the relations between co-ordinate systems; time; ephemerides; the earth's figure and corrections to observed altitules; instruments; and the identification of stars and constellations. The apparent motions of sun and

planets are explained in somewhat more detail than in many similar texts. The transformation from sidereal to solar time is given in some detail—no doubt because beginning students find this fundamental problem difficult to master. The approximate methods used by air navigators for determining position are also outlined. The chapter on instruments is expanded considerably over that in the second edition to include the description of modern solar attachments for the surveyor's transit as well as some details concerning the bubble sextant. The suggestions for observing and methods of determining errors indicate the difficulties encountered in obtaining accurate astronomical observations with small instruments.

Part II, "Engineering Astronomy," discusses only problems which can be solved from observations made with the engineer's transit; it thus eliminates certain navigational problems as well as geodetic methods for which high-precision instruments are required. The methods of determining latitude, time and longitude, and azimuth from observations of both sun and stars are discussed in considerable detail, with modern examples worked out in all cases. For most methods a discussion of errors is included and the best observational techniques are noted. The problem of the convergence of meridians, which is not given in similar texts, is discussed and is a desirable addition to the book.

The typography and leatherette binding are excellent and it would seem that the book should be very useful for courses in engineering astronomy.

K. O. W.

OUT OF OLD BOOKS

By Helen Sawyer Hogg

The Titius-Bode Law and the Discovery of Ceres

IT would appear that many astronomers of the present generation are somewhat confused in their impressions of the discovery of Bode's law and its influence on the discovery of the first asteroid, Ceres. During the last three years this so-called law has come again into prominence with the important theory evolved by von Weizsäcker on the origin of the solar system. This theory when applied with reasonable mathematical constants, emerges with Bode's formula for planetary distances, $r = a + b.2^n$, where a and b are constants with value 4 and 3 respectively. Weizsäcker's theory, published in the *Zeitschrift für Astrophysik,* 1945, has been reviewed by Chandrasekhar in *Reviews of Modern Physics,* 1946, and by Gamow and Hynek in the *Astrophysical Journal,* March 1945.

It is a return to the idea that the planets were formed from a single star. It postulates our sun as surrounded by a gaseous ring, which condensed into planetesimals, and, after an interval of about 10^8 years, built up into planets. The chief new assumption is that one-tenth of the solar mass was distributed in this ring, 99 per cent. of which was composed of the lighter elements hydrogen and helium, which have long since dissipated into space, thereby leaving the present planets with 98 per cent. of the angular momentum of the solar system, but only one-tenth of one per cent. of the mass. The relationship of Bode's Law is worked out from numerical considerations of the possible orbits of the "vortices" of particles round the sun.

The present confusion about the development of the law, and whether it was directly responsible for the discovery of Ceres is probably due mostly to the tendency of some text-books of the twentieth century to condense details in a manner which is somewhat ambiguous, and liable to misinterpretation, even by careful readers.

The so-called Bode's law was proposed originally by Titius of Wittenberg, although Kepler in the previous century had called attention to the curious gap in the progression of planetary distances

between Mars and Jupiter. A clear and reliable account of the development of this law is given by W. T. Lynn, in a letter to *Observatory*, vol. xvi, p. 178, 1893, and we quote this letter in its entirety, with its references to the original papers. We note that while Titius noticed the arithmetical progression and the gap, he appears to have thought that the gap might be filled by the discovery of satellites of Mars or Jupiter. Bode's name became attached to the law, however, when he correctly prophesied that a new planet would be found (with period 4½ years) occupying the gap. Not one large planet, but a host of tiny ones, have now been found in this space. The translation of Bode's treatise of 1802, mentioned by Lynn, is to be found in the *Source Book of Astronomy*, by Shapley and Howarth.

The so-called Law of Titius or Bode.

Gentlemen,—

The failure of this so-called law of planetary distances after Uranus has caused that much less interest has been felt in it since the discovery of Neptune than before. Still some facts seem to have been forgotten respecting its first enunciation to which it may be well to call attention. That there was a species of progression in the planetary distances, in which a gap occurred between Mars and Jupiter, had been noticed by Kepler. But the numerical expression of this in the form $4,\ 4+3,\ 4+3\times 2,\ 4+3\times 2^2$, &c. was first put forth by J. D. Titius, of Wittenberg, and as Bode mentions this in his treatise, "Von dem neuen zwischen Mars und Jupiter entdeckten achten Hauptplaneten des Sonnensystems," it is somewhat strange that the progression should have acquired the name of Bode's law. (Prof. Newcomb, oddly enough, calls it Bode's law in one place in the index to his "Popular Astronomy", but the law of Titius in the text to which reference is there made.) Probably, however, this is in great measure due to the fact that Bode, as Sir John Herschel writes, "would appear to have first drawn attention to this interpretation of its interruption," *i.e.*, to its indication of the probability of the existence of an unknown planet, smaller or less capable of reflecting light than the others, revolving between the orbits of Mars and Jupiter.

I have thought, therefore, that it would be of some interest to your readers to refer to the different idea of Titius. It is in a note to a German translation of the "Contemplation de la Nature", of Charles Bonnet, that he gives this numerical progression, pointing out the gap. He then adds (I quote from the second edition, published in 1772):—"Und der Bauherr sollte diesen Raum ledig gelassen haben? Nimmermehr! Lässt uns zuversichtlich setzen, dass dieser Raum sonder Zweifel den bisher noch unentdeckten Trabanten des Mars zugehöre; lässt uns hinzuthun, dass vielleicht auch Jupiter noch etliche um sich habe, die bis isst noch mit keinem Glase gesehen werden." It would be attributing

very large orbits to these hypothetical satellites of Mars and Jupiter to suppose that they filled in any considerable part of the gap between the orbits of those planets; nor can these words be twisted into a prophecy of the discoveries of Professors Asaph Hall and Barnard. Still Titius seems to have suggested new satellites rather than planets. Bode, on the other hand, calling attention to the progression (in the second edition of his 'Anleitung zur Kenntniss des gestirnten Himmels,' published in 1772), confidently expresses the view that it points to the existence of another primary planet, which would, he remarks, occupy, according to Kepler's third law, about 4½ years in its revolution round the Sun. Nor did he fail, on the discovery of Ceres in 1801, to claim (in the treatise referred to above) that his conjecture was thus confirmed. He probably little thought that she was to be followed by hundreds of sisters, most of them more diminutive than herself. The discovery, however, of another planet (Pallas), early in the following year, led Herschel to think it probable that the number of those bodies (for which he suggested the name asteroids, since felt to be unsuitable) was great.

Yours faithfully,

W. T. LYNN.

Blackheath, 1893 Mar. 13.

It is interesting to note that over a century ago an attempt was made to apply the same type of law to the distances of the satellites of the solar system from their primaries. In the same volume of *Observatory*, page 359, Lynn calls attention to the attempt of Prof. Challis in this direction. Prof. Challis of Cambridge is known for his pre-discovery work on the planet Neptune, with Adams's position, and his actual viewing of the planet before its discovery, though he failed to recognize it for what it was.

From the same volume, p. 359.

The so-called Law of Bode as applied by Challis to the Satellites.

Gentlemen,—

In vol. iii of the 'Transactions of the Cambridge Philosophical Society,' the late Prof. Challis contributed a paper (read on December 8, 1828) "On the Extension of Bode's Empirical Law of the Distances of the Planets from the Sun to the Distances of the Satellites from their Respective Primaries," in which, by certain modifications of the so-called law, expressed in the more general form—

$$a,\ a+b,\ a+rb,\ a+r^2b,\ \&c.,$$

he considered that he was able to show that it is applicable to the satellites of the solar system. And he draws the "curious inference, which is equally certain with the reality of the law," that "there can be no planet nearer the Sun than Mercury, and no satellite nearer the several primaries than the nearest of those

in each system, which have been discovered." The last part of this inference reads oddly now, in view of Prof. Barnard's recent discovery in the system of Jupiter. But the addition, in 1848, of Hyperion (seventh in order of distance) to the system of Saturn was equally inconsistent with the conclusions formed in this paper. Prof. Challis was obliged to introduce an extra term in considering the satellites of this planet, and express their distances in the form—

$$a,\ a+b,\ a+rb,\ a+r^2b,\ a+r^4b,\ a+r^3r'b,\ a+r'\ r'^2b.$$

The r' therefore had to be introduced for Titan, no. 6 in order of distance, and Hyperion cannot be fitted into the series, which appears, when worked out numerically, in the shape—

$$4,\ 4+1,\ 4+1\times2,\ 4+1\times2^2,\ 4+1\times2^3,\ 4+1\times2^3\times3,\ 4+1\times2^3\times3^2;$$

or 4, 5, 6, 8, 12, 28, 76.

For Uranus, Challis obtained conformity with a series of the same form as that for Jupiter* ($a,\ a+b,\ a+rb,\ a+r^2b$), adding two more terms of the form $a+r^4b,\ a+r^7b$. But this is by accepting the whole of the six satellites announced by Herschel, four of which have long since ceased to be regarded as real. Challis remarks that their existence had been doubted, but thinks that the conformity of their distances to this law confirms their reality, though they were probably smaller than the two which were undoubted. The so-called law, however, cannot apparently be fitted in any shape to the distances of the four satellites which are now known and probably form the whole system. These distances are approximately in the proportion 4, 5½, 9, 12, or 3, 4, 7, 9.

The discovery of Neptune, in 1846, it need hardly be said, showed that the so-called law of Titius or Bode failed in the planetary system itself after Uranus.

Yours faithfully,

W. T. Lynn.

Blackheath, 1893 Sept. 4.

Although Grant, in his *History of Physical Astronomy*, 1852, overlooks the contribution of Titius to Bode's law, he gives an excellent account of the relationship between this law and the discovery of the first asteroid. This account is given in a shortened form by C. A. Young in the well-known text, *General Astronomy*. We see from Grant's account, page 237 (which we quote) that the astronomers hunting to fill the gap shown by Bode's law were not the actual discoverers of Ceres.

In 1772, Bode published a treatise on astronomy in which he first announced the singular relation between the mean distances of the planets from the sun, which has since been distinguished by his name. This relation . . . exhibited in a very striking light the exaggerated leap from Mars to Jupiter, and suggested the strong probability of a planet revolving in the intermediate region. This

*Numerically for Jupiter 7, $7+4$, $7+4\times2^2$, $7+4\times(2^2)^2$, . . . or 7, 11, 17, 32, . . .

conjecture was rendered still more plausible by the discovery of the planet Uranus, in 1781, the distance of which from the sun was found to conform exactly to the law of Bode. In Germany, especially, a strong impression had been produced that a planet really existed between Mars and Jupiter; and, through the active exertions of De Zach, an association of twenty-four astronomers was formed, having for its object to effect the discovery of the unknown body. For this purpose the zodiac was divided into twenty-four zones, one of which was to be explored by each astronomer; and the conduct of the whole operation was placed under the superintendence of Schroeter. Soon after the formation of this society the planet was discovered, but not by any of those astronomers who were engaged expressly in searching for it. Piazzi, the celebrated Italian astronomer, while engaged in constructing his great catalogue of stars, was induced carefully to examine, several nights in succession, a part of the constellation Taurus, in which Wollaston, by mistake, had assigned the position of a star which did not really exist. On the 1st January, 1801, Piazzi observed a small star, which, on the following evening, appeared to have changed its place. On the 3rd he repeated his observations, and he now felt assured that the star had a retrograde motion in the zodiac. The daily change of position in right ascension was 4′, and the change in declination towards the north pole was 3′ 30″. On the 24th of January, he transmitted an account of his discovery to Oriani and Bode, communicating the positions of the star on the 3rd and 23rd of that month, and adding that its motion, from being retrograde on the 11th, had become direct on the 13th of the same month. Piazzi continued to observe the star until the 11th of February, when he was seized with a dangerous illness which completely interrupted his labours. His letters to Oriani and Bode did not reach these astronomers until the latter end of March, but the planet had then approached too near the sun to admit of their obtaining a verification of his discovery by actual observation, and it was necessary for this purpose to wait until the month of September, when the planet would have effectually extricated itself from the solar rays. Its re-discovery, after the lapse of so considerable a period subsequent to the most recent observation, could not be expected to be accomplished without a pretty accurate knowledge of the orbit in which it was moving; but the data communicated by Piazzi were insufficient for this purpose. They merely served to indicate that the body revolved in a circular orbit between Mars and Jupiter, at a distance agreeing very nearly with that assigned by Bode's law, and so far offered a satisfactory confirmation of the views of the German astronomers. Meanwhile Piazzi, fearing lest he should be deprived in any degree of the glory attached to the discovery of the planet, communicated to astronomers all the observations of it made by him down to the 11th February. Gauss found that they might be all satisfied within a few seconds, by an elliptic orbit, of which he calculated the elements; and, with the view of aiding astronomers in searching for the planet, that illustrious geometer also computed an ephemeris of its motion for several months. After a careful examination of its geocentric path, the planet was finally discovered by De Zach on the 31st of December, and by Olbers on the following

evening. A year had therefore elapsed between the original discovery of the planet by Piazzi and its subsequent re-discovery by the German astronomers. Piazzi conferred on it the name of Ceres, in allusion to the titular goddess of Sicily, the island in which it was discovered; and the sickle has been appropriately chosen for its symbol of designation.

Readers may find the translation of the letter Piazzi wrote Bode to announce the discovery of the new object (referred to as a comet), in the *Source Book of Astronomy* already mentioned.

NOTES AND QUERIES

Copernicus's "De Revolutionibus", its Nature and Contents

From "Copernicus, the Founder of Modern Astronomy" by Angus Armitage, 1938, p. 68:

The body of the work falls into six Books, each subdivided into a number of chapters. In Book I, Copernicus sets forth his general arguments for believing in the mobility of the earth, and for substituting the heliocentric for the geocentric point of view; he sketches the heliocentric arrangement of the solar system in broad outlines, and he gives the modern explanation of the seasons. The Book concludes with some elementary plane and spherical trigonometry, including a Table of Chords, or more precisely, of sines. Book II deals with spherical astronomy (definitions of the circles of the celestial sphere, transformation of co-ordinates, etc.), and treats of problems connected with the rising and setting of the sun and of other heavenly bodies. As the treatment of such phenomena is independent of rival physical theories as to their causation, no part of this Book will again concern us except the star-catalogue with which it concludes. Coming down now to detailed geometrical schemes of the motions in the solar system, Copernicus treats of the earth's several motions, and the elements of its orbit, in Book III. In Book IV he deals with the theory of the moon's motions, and with the determination of the distances of the sun and moon. In Book V, the longest and the most vital of the six, he investigates the motions in longitude of the five planets, and the sizes of their orbits in relation to that of the earth. In Book VI the motions of the planets in latitude are considered.

C. A. C.

Historical Notes in Scientific Text-Books

From the preface to "Christian Huygens, and the Development of Science in the Seventeenth Century" by A. E. Bell (1947):

A protest may here be made against the practice of inserting historical notes in scientific text-books without regard for the conflict of old and modern ideas. Once a subject has become well developed, the logical and not the historical method is to be desired, for so much of the earlier science can be

properly understood only with a really adequate study. The great scientist of the past tends soon to appear a distant and indeed thoroughly dead sort of figure. The modern scientist to a large extent accepts his reputation on trust and has little time and often less inclination to read the original work. How many now read Galileo's *Discourses* or Newton's *Principia*? It is otherwise in art and in literature. If science is to become a more widely accepted means of education (in the sense of a form of culture) there is need of more works on its history. A modern estimate can do much to revivify the past, and present these great men, its creators, in a clearer light.

C. A. C.

Statement Regarding Fees

The General Council of the Royal Astronomical Society of Canada regrets that it has been found necessary to increase the membership fees of the Society and subscription price of the publications. Henceforth the annual membership fee will be $3.00 per year, and life membership $40.00. The price of single numbers of the bi-monthly *Journal* will be fifty cents, and the annual *Observer's Handbook*, forty cents.

E. J. A. Kennedy,
General Secretary.

The Royal Astronomical Society of Canada

OFFICERS FOR 1948

Honorary President—THE HONOURABLE GEORGE A. DREW, Prime Minister and Minister of Education for the Province of Ontario
President—J. W. CAMPBELL, PH.D., Edmonton, Alta.
First Vice-President—ANDREW THOMSON, M.A., Toronto.
Second Vice-President—C. S. BEALS, PH.D., Ottawa
General Secretary—E. J. A. KENNEDY, 3 Willcocks St., Toronto 5
General Treasurer—J. H. HORNING, M.A., Toronto
Recorder—H. W. BARKER, Toronto
Librarian—D. W. BEST, D.D., Toronto
General Council—ALBERIC BOIVIN, B.Sc., Quebec, P.Q.; A. J. COOK, Edmonton, Alta.; G. HARPER HALL, Montreal, P.Q.; H. R. KINGSTON, PH.D., London; RUTH J. NORTHCOTT, M.A., Toronto; L. T. S. NORRIS-ELYE, Winnipeg, Man.; ROBERT PETERS, Victoria, B.C.; L. R. ROGERS, B.A., Windsor; W. D. STEWART, B.A., Hamilton; H. D. SMITH, PH.D., Vancouver, B.C.; M. M. THOMSON, B.A., Ottawa; F. L. TROYER, Toronto.

TORONTO CENTRE

Honorary President—C. A. CHANT, PH.D.
President—J. F. HEARD, PH.D.
First Vice-Pres.—A. R. CLUTE, K.C.
Second Vice-Pres.—F. S. HOGG, PH.D.
Secretary—FREDERIC L. TROYER, 32 Front St. W.
Treasurer—T. H. MASON
Recorder—J. R. TUCK, D.EDUC.
Council—C. A. CROSS; HELEN S. HOGG, PH.D.; W. R. SHERRICK; F. K. DALTON, B.SC.; RAYMOND PEARCE; R. E. WILLIAMSON, PH.D.; D. S. AINSLIE, PH.D.; F. T. GRAHAM; J. R. COLLINS; S. C. BROWN; REV. D. W. BEST; MISS R. J. NORTHCOTT, M.A.; and H. W. BARKER.

OTTAWA CENTRE

Honorary President—HOYES LLOYD, M.A.
President—M. M. THOMSON, B.A.
First Vice-Pres.—P. M. MILLMAN, PH.D.
Second Vice-Pres.—M. J. S. INNES, M. A.
Secretary—MISS C. B. HICKS, B.A., B.L.S., 43 Florence St., Apt. 2
Treasurer—STANLEY A. MOTT
Council—K. C. MACLURE, B.SC.; R. G. MADILL, B.A.; W. S. MCCLENAHAN, B.A.; A. H. MILLER, M.A.; R. M. STEWART, M.A.; and Past Presidents MISS M. S. BURLAND, B.A.; T. L. TANTON, PH.D., and F. W. MATLEY.

HAMILTON CENTRE

Honorary President—W. T. GODDARD
President—T. M. NORTON
Vice-Pres.—W. J. MCCALLION, M.A.
Curator—G. E. CAMPBELL, M.A.
Secretary-Treasurer—GEO. MURCHIE, 77 Fennel Avenue W.
Council—REV. E. F. MAUNSELL, M.A.; A. E. JOHNS, PH.D.; J. R. GRAHAM; F. SCHNEIDER; W. S. MALLORY, M.A.; F. SISMAN; W. D. STEWART, B.A.; D. G. BURNS; L. O. JONES; O. J. PATON.

WINNIPEG CENTRE

Honorary President—DR. L. A. H. WARREN
President— L. KOSER
Vice-Pres.—H. RASMUSSEN
Treasurer—MISS M. WATTERSON
Press Secretary—C. D. CARD
Recorder—MISS B. SHARMAN, Rupert's Land School
Council—MISS O. ARMSTRONG; D.P.R. COATS; MRS. J. NORRIS; L. T. S. NORRIS-ELYE; V. C. JONES; P. G. MORSE; A. V. THOMAS; E. R. GARDINER.

MONTREAL CENTRE

Honorary President—G. HARPER HALL
President—J. W. DUFFIE
Honorary Vice-Pres.—DR. A. NORMAN SHAW
Vice-Pres.—F. DEKINDER
Secretary—HENRY F. HALL, 1441 Drummond St.
Treasurer—C. N. S. YARNELL
Recorder—MISS I. K. WILLIAMSON
Director of Observations—DELISLE GARNEAU
Librarian—C. M. GOOD
Council—A. M. DONNELLY; DR. D. E. DOUGLAS; ROSS FORD; F. W. HENSHAW; A. KNEELAND A. R. MCLENNAN; F. P. MORGAN; W. H. C. MORTON; DR. W. BRUCE ROSS; E. RUSSELL PATERSON; D. P. GILLMOR.

VICTORIA CENTRE

Honorary President—R. M. PETRIE, PH.D.
President—A. MCKELLAR, PH.D.
First Vice-Pres.—J. S. STEVENSON, PH.D.
Second Vice-Pres.—MRS. J. R. NOBLE
Secretary-Treasurer—MISS J. K. MCDONALD, Dominion Astrophysical Observatory
Recorder—G. L. DARIMONT
Director of Telescopes—ROBERT PETERS
Librarian—MISS Y. LANGWORTHY
Council—R. S. EVANS; JOHN JERVIS; E. H. POPE; H. A. REID; M. TRUEMAN; MRS. C. S. YARWOOD.

LONDON CENTRE

Honorary President—DR. H. R. KINGSTON
President—DR. A. J. WATT
Vice-President—O. Kilburn
Past-Pres.—DR. R. H. COLE
Secretary-Treasurer—A. EMSLEY, 831 Richmond St.
Council—E. E. O'CONNOR; M.O. CULBERT; J. W. BRYCE; MRS. A. DAVIES; J. C. HIGGINS.

(Continued at bottom of next page)

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
1890-1948

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton, London and Windsor, Ontario; Winnipeg, Man.; Saskatoon, Sask.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as nearly 1300 members of these Canadian Centres, there are over 500 members not attached to any Centre, mostly resident in other nations, while some 140 additional institutions or persons subscribe to our publications.

The Society publishes a bi-monthly "Journal" containing about 350 pages and a yearly "Observer's Handbook" of 80 pages. Single copies of the "Journal" are 50 cents, and of the "Handbook," 40 cents.

Membership is open to anyone interested in astronomy. Annual dues, $3.00; life membership, $40.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 3 Willcocks St., Toronto.

VANCOUVER CENTRE

Honorary President—G. M. SHRUM, PH.D. *President*—LT. COMM. C. A. MACDONALD
Vice-President—P. J. SYKES *Recording-Secretary*—C. W. DEANS
Corresponding-Secretary—M. T. SPENCE, 8305 Fremlin Street
Treasurer—MISS G. W. OWEN
Council—N. D. B. PHILLIPS; MRS. C. A. ROGERS; MRS. L. ANDERSON; A. OUTRAM; DR. O. BLUH; N. BARTON; K. C. MANN, PH.D.

EDMONTON CENTRE

Honorary President—J. W. CAMPBELL, PH.D. *President*—D. B. SCOTT
Vice-Pres.—ALEC STOCKWELL *Treasurer*—MISS A. M. P. SMITH
Secretary—E. H. GOWAN, PH.D., University of Alberta *Librarian*—E. S. KEEPING
Council—F. C. BLOWER, H. M. BUTT; S. G. DEANNE, H. A. MCGREGOR; H. DYKSLEY.

QUEBEC CENTRE

Patron—MGR. FERDINAND VANDRY, P.A., V.G., Rector of Laval University
Honorary Chairman—ARTHUR AMOS *Chairman*—J.-LUCIEN POULIOT
First Vice-Chairman—LIONEL LEMIEUX *Second Vice-Chairman*—GEO.-ETIENNE GAGNÉ
Secretary-Treasurer—PAUL-H. NADEAU, 275 rue St. Cyrille
Council—ABBÉ ROSARIO BENOÎT; JEAN-CHS. MAGNAN; LLOYD MCWILLIAMS; CLAUDE FRÉMONT; CHS.-A. GIROUX; OSCAR VILLENEUVE; ALBÉRIC BOIVIN; LÉON-D. DESCARREAUX.

WINDSOR CENTRE

Honorary President—E. R. PHELPS. PH.D. *President*—DANIEL C. BAWTENHEIMER
Vice-Pres.—CHARLES A. BELL, B.A. *Treasurer*—JACK EVZOVITCH, B.S.E.E.
Secretary—RUSSELL G. WARWICK, B.A., 1587 Moy Ave.
Librarian—BEVERLEY CARSON *Asst. Librarian*—DONALD CRAPPER
Council—MRS. MARGARET BACK; HUGH S. CUNNINGHAM, B.A.; W. ALMON HARE, B.A.Sc.; F. W. C. JONES, B.S.; GREGORY RAWLINGS, B.A.; W. A. ROBERSON; G. S. SPRACKLIN; W. J. PERSON; E. M. KREBSER, B.A.Sc.; D. GEAUVREAU; HENRY LEE, B.S.E.E.; LORNE ROGERS, B.A.; CAMERON MONTROSE, B.Sc.; and Past President CYRIL B. HALLAM, B.A.

SASKATOON CENTRE

Honorary President—E. L. HARRINGTON, PH.D. *President*—J. H. ERWIN, B.A., B.ED.
Vice-Pres.—W. BUSCOMBE, B.A.
Secretary—MISS A. E. HIEBERT, B.A., Dept. of Mathematics, University of Sask.
Recorder—W. PETRIE, PH.D. *Treasurer*—W. HAWKINS, M.SC.
Council—J. R. MARTIN; W. H. WHITE, PH.D.; B. W. CURRIE, PH.D.; J. E. JOHNS, PH.D.; L. N. LEVALLEY.

GUELPH CENTRE

President—HENRY H. WESTOBY *Vice-Pres.*—W. T. PATTERSON, R.O.
Secretary—F. E. BRAUCHT, Collegiate and Vocational Institute
Treasurer—S. B. MACKAY
Council—W. R. REEK, M.B.E., F.R.A.S.; PROF. R. C. MOFFATT; PROF. ARTHUR DAVEY; PROF. F. E. CHASE; T. J. HEGG, B.S.A.; F. A. HAMILTON, B.A.; and H. W. SEEKINS.

CENTRE FRANCAIS DE MONTREAL

President Honoraire—DR. J.-ERNEST GENDREAU *President*—DELISLE GARNEAU
Vice-Pres.—J.-E. GUIMONT
Secretaire-Tresorier—JOSEPH LEDUC, 1430 rue St. Denis, Montreal 18
Membres du Conseil—FR. ROBERT, F.E.C., MM. ARTHUR AMOS, IVAN JOBIN; JEAN-JACQUES LEFEBVRE; JACQUES DESJARDINS ET BERNARD BOUCHER.